

production of free radicals that would inhibit the propagation of the chemical reactions of the combustion reactions.

Manufacturing of a fire-extinguishing agent according to the proposal would begin with the formulation of a suitable polymer (e.g., a polybromostyrene) that would contribute free radicals to the combustion process. The polymer would be dissolved in a suitable hydrocarbon

liquid (e.g., toluene). Water would be dispersed in the polymer/toluene solution, then another hydrocarbon liquid (e.g., hexane) that is not a solvent for the polymer would be added to the mixture to make the dissolved polymer precipitate onto the water droplets. The resulting polymer-coated droplets would be removed from the coating mixture by filtration, dried, and stored for use.

This work was done by Clyde F. Parrish of Kennedy Space Center.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (321) 867-8130. Refer to KSC-12236.

Multiaxial Temperature- and Time-Dependent Failure Model

This model should be applicable to a variety of materials.

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A temperature- and time-dependent mathematical model predicts the conditions for failure of a material subjected to multiaxial stress. The model was initially applied to a filled epoxy below its glass-transition temperature, and is expected to be applicable to other materials, at least below their glass-transition temperatures. The model is justified simply by the fact that it closely approximates the experimentally observed failure behavior of this material: The multiaxiality of the model has been confirmed (see figure) and the model has been shown to be applicable at temperatures from -20 to 115 °F (-29 to 46 °C) and to predict tensile failures of constant-load and constant-load-rate specimens with failure times ranging from minutes to months.

The model is embodied in the following equation for the failure condition:

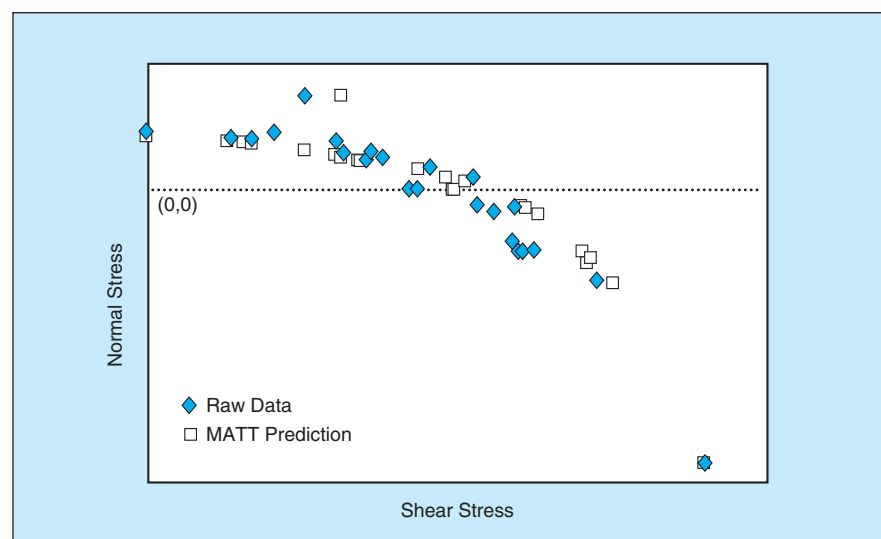
$$AP^2J_2 + BP_1 = 1$$

where

- A and B are parameters that define the shape of an ellipsoidal failure surface in multiaxial stress space;
- P is a scaling factor that accounts for the temperature and time dependences of the material;
- J_2 is the second deviatoric stress invariant, given by

$$\sigma_{11}^2 + \sigma_{22}^2 + \sigma_{33}^2 - \sigma_{11}\sigma_{22} - \sigma_{11}\sigma_{33} - \sigma_{22}\sigma_{33} + 3(\sigma_{12}^2 + \sigma_{13}^2 + \sigma_{23}^2)$$

- I_1 is the first stress invariant, given by $\sigma_{11} + \sigma_{22} + \sigma_{33}$;
- the numerical subscripts denote Cartesian coordinate axes; and
- σ_{ij} denotes the stress.



Experimental and Predicted Failure Points are plotted here for "napkin-ring" specimens of a filled epoxy that were loaded with both normal and shear stresses at a temperature of 70 °F (21 °C).

In the special case of constant P , this model is equivalent to a modified Drucker-Pager model, and to the Tsai-Wu failure model that is traditionally used in evaluating composite materials.

The model is calibrated by use of data from tensile and shear failure experiments. Data from tensile-adhesion and shear-adhesion failure tests of the material to which the model was initially applied show that the ratio between shear and tensile failure loads has a value of ≈ 0.8 , independent of time and temperature. This constant ratio, in combination with one sensor data point, can be used to calculate the values of A (1.0 for this material) and B (0.31754 for this material).

The value of the scale factor P is simply whatever value is needed to

make a given failure surface pass through a known failure point for a given temperature and failure time. Hence, for example, once A and B are known, P as a function of time and temperature can be determined simply by solving the basic model equation for P and then inserting stress values from tensile or shear tests that involve known failure times and temperatures.

This work was done by David Richardson, Michael McLennan, Gregory Anderson, David Macon, and Alicia Batista-Rodriguez of Thiokol Propulsion Corp. for Marshall Space Flight Center. For further information, please contact the company at (435) 863-3511. MFS-31750